

# **ADVANCED LARGE-SCALE BRAIDING DEVELOPMENT AND DEMONSTRATION**

## **1.0 Introduction**

NASA is developing Hypersonic Inflatable Aerodynamic Decelerators (HIADs) for application to future robotic and human missions requiring atmospheric entry. HIADs offer considerable system mass and volume savings over rigid aeroshell technology. To advance HIAD development and identify technical challenges with development of a 10 meter class of HIAD, testing of individual elements is needed to meet performance requirements for potential flight demonstrations. One of the challenges is developing soft-good materials and fabrics for a deployable thermal protection system (TPS).

This Statement of Work (SoW) defines a fabrication effort to be performed by the Contractor that will demonstrate an ability to manufacture a low-angle biased two dimensional fabric through a braiding process that otherwise cannot be achieved using a standard fabric weaving process. The primary objective is to establish a manufacturing method that uses brittle silicon carbide ceramic yarns to obtain a nominal +/- 60° biased biaxial braided tube with a diameter of 24 inches of sufficient length to manufacture a deployable TPS with a diameter of at least 20 feet. The work detailed herein is defined as a subscale manufacturing effort that will demonstrate the feasibility of using industry standard braiding methods and equipment to obtain a refractory cloth of length and quality sufficient for the manufacture of a deployable TPS.

## **2.0 Objectives**

The Contractor shall identify and demonstrate braid fabrication methods based on the requirements in this SoW. The contract scope of work shall include the tasks listed below. The detailed technical requirements for these tasks are provided in Tasks 3.2 and 3.4 of this SoW. Successful completion of Task 3.2 is required to obtain Government authorization to proceed to Task 3.4. The Government decision whether or not to proceed with Task 3.4 will be provided following the Midterm Contract Review Task 3.3.

The SoW for the HIAD Advanced Large-Scale Braiding Development and Demonstration SoW include technical tasks identified as:

- 3.1 Kick-off Meeting**
- 3.2 Subscale Braided Fabric**
- 3.3 Midterm Contract Review**
- 3.4 Large Scale Braided Fabric**
- 3.5 Final Contract Review**

### **3.0 Task Technical Details**

The primary work provided for in the contract is divided into two major tasks for the purpose of, first demonstrating proof of concept through a preliminary fabrication trial using a lower temperature capable candidate ceramic yarn material, and second, extending those capabilities successfully developed and demonstrated to a higher temperature capable silicon carbide yarn. The lower temperature candidate yarn shall be Nextel™ 440 which has been chosen because it is a lower cost material that possesses mechanical and manufacturing durability properties comparable to a higher temperature capable, and higher cost CG-Nicalon™ yarn. The Subscale Braided Fabric Task 3.2 addresses the technical requirements for braiding brittle ceramic yarns. Successful completion of Task 3.2 is required to assess the probability of successfully completing the Large-scale Braiding Task 3.4. An examination of the progress performed during the Subscale Braided Task 3.2 shall be conducted through a mid-term review. Following successful completion of the Tasks 3.2 and 3.3, the Government will assess the risks to successfully completing Task 3.4 and make a decision on executing Task 3.4. The Contractor must have a written authorization to proceed from the Government before executing work under the Large-scale Braided Fabric Task 3.4.

#### **3.1 Kick-off Meeting**

Within 7 days of the contract award date, the Contractor shall participate in a Kick-off Meeting that will be held via telephone and web conferencing. The purpose of the Kick-off Meeting is to provide a forum at which the Government and the Contractor can review the detailed requirements described in this SoW. The Contractor is not required to present information at the Kick-off Meeting.

#### **3.2 Subscale Braided Fabric**

The Contractor shall produce a subscale biaxial braid using 2000 denier Nextel™ 440 plied yarn that is capable of being made into a fabric which meets the following required specifications:

- 3.2.1 The braid shall have a minimum diameter of 11 inches (+/-0.5 inches)
- 3.2.2 The braid shall have a minimum length of 60 inches (+/-1.0 inches)
- 3.2.3 The bias braid angle shall be  $\pm 60$  degrees (+/-2 degrees)
- 3.2.4 The braid shall have coverage defined by 24 ends (yarns) per inch (epi) in each of the bias directions with 1 end (yarn) per carrier
- 3.2.5 The braided fabric shall be cut at one location along the axis of the tube to form a flat fabric having a nominal minimum width of 34.5 inches (+/-1.0 inches) and a nominal length of 59 inches (+/-0.5 inches)

OR

- 3.2.1 The braid shall have a minimum diameter of 21 inches (+/-0.5 inches)
- 3.2.2 The braid shall have a minimum length of 60 inches (+/-1.0 inches)
- 3.2.3 The bias braid angle shall be  $\pm 60$  degrees (+/-2 degrees)

- 3.2.4 The braid shall have coverage defined by 12 ends (yarns) per inch (epi) in each of the bias directions with 2 ends (yarn) per carrier
- 3.2.5 The braided fabric shall be cut at one location along the axis of the tube to form a flat fabric having a nominal minimum width of 66 inches (+/-1.0 inches) and a nominal length of 59 inches (+/-0.5 inches)
- 3.2.6 The Contractor shall submit the technical details that will be used to manufacture the braid to the Government prior to fabrication start.

The Contractor shall deliver the subscale braided fabric required in subsection 3.2.5 **[Deliverable 4.1]** within 45 days following the contract award date. The Contractor shall produce and submit a written Subscale Braided Fabric Technical Report **[Deliverable 4.2]** within 7 days following completion of the Subscale Braided Fabric Task 3.2. The written report shall include a narrative of the work accomplished during the Subscale Braided Fabric performance period, the processes and facilities used during fabrication, and identification of potential problems and proposed corrective actions for executing the Large-Scale Braided Fabric Task 3.4.

### **3.3 Midterm Review**

The Contractor shall conduct a telephone and web conferencing meeting with the contract technical representative at the end of the subscale braid fabrication process. The Contractor shall present a summary of the results from the Subscale Braided Fabric Task 3.2 together with the technical details that will be used to successfully complete the work provided for in Task 3.4. A review of the midterm results and the proposed technical details to be used for the Large-Scale Braided Fabric Task 3.4 shall be used by the Government to make a decision whether or not to proceed with Task 3.4. Within 7 days following the midterm review the Government will complete its assessment and determine whether or not to authorize the Contractor to proceed with Task 3.4.

### **3.4 Large-Scale Braided Fabric**

The Contractor shall produce a large-scale biaxial braid using Government Furnished CG-Nicalon<sup>TM</sup> silicon carbide yarn provided in sufficient quantity to form a fabric which meets the following required specifications:

- 3.4.1 The braid shall have a minimum diameter of 11 inches (+/-0.5 inches)
- 3.4.2 The braid shall have a minimum length of 240 inches (+/-1.0 inches)
- 3.4.3 The bias braid angle shall be  $\pm 60$  degrees (+/-2 degrees)
- 3.4.4 The braid shall have coverage defined by 24 ends (yarns) per inch (epi) in each of the bias directions with 1 end (yarn) per carrier
- 3.4.5 The braided fabric shall be cut at one location along the axis of the tube to form a flat fabric having a nominal minimum width of 34.5 inches (+/-1.0 inches) and a nominal length of 235 inches (+/-0.5 inches)

OR

- 3.4.1 The braid shall have a minimum diameter of 21 inches (+/-0.5 inches)
- 3.4.2 The braid shall have a minimum length of 240 inches (+/-1.0 inches)
- 3.4.3 The bias braid angle shall be  $\pm 60$  degrees (+/-2 degrees)
- 3.4.4 The braid shall have coverage defined by 12 ends (yarns) per inch (epi) in each of the bias directions with 2 ends (yarn) per carrier
- 3.4.5 The braided fabric shall be cut at one location along the axis of the tube to form a flat fabric having a nominal minimum width of 66 inches (+/-1.0 inches) and a nominal length of 235 inches (+/-0.5 inches)

The Contractor shall deliver the large-scale braided fabric required in subsection 3.4.5 **[Deliverable 4.3]** within 60 days of authorization to proceed with the Large-Scale Braided Fabric task and receipt of Government supplied CG-Nicalon™ yarn.

### 3.5 Final Contract Review

The Contractor shall produce and submit a written Final Technical Report **[Deliverable 4.4]** within 30 days following completion of the Large-Scale Braided Fabric Task 3.4. The written report shall include a narrative of the work accomplished during the contract period together with a discussion of successes, technical challenges, and potential areas for improvement to the fabrication process.

## 4.0 Milestones and Deliverable Schedule

The Contractor shall deliver the following items FOB Destination. All deliverables shall be delivered with unlimited rights and unrestricted rights as defined under FAR 52.227-14 (Rights in Data - General), as modified by NFS 1852.227-14.

| Item No. | Ref.  | Deliverable Description    | Qty. | Due Date                                     | Delivery Instructions                                       |
|----------|-------|----------------------------|------|--|---|
| 4.1      | 3.2.5 | Nextel™ 440 braided fabric | 1 EA | Within 45 calendar days after contract award | Physically Delivered to Government Technical Representative |

| Item No. | Ref.  | Deliverable Description                  | Qty. | Due Date   | Delivery Instructions   |
|----------|-------|--|------|--|---|
| 4.2      | 3.2.6 | Subscale Braided Fabric Technical Report | 1 EA | Within 7 calendar days after Nextel™ 440 braided fabric delivery                   | Delivered to Government Technical Representative and Contract Officer electronically in accordance with NFS 1852.235-73 and contract. |
| 4.3      | 3.4.5 | CG-Nicalon™ braided fabric               | 1 EA | Within 60 calendar days after Task 3.4 authorization to proceed and receipt of GFP | Physically Delivered to Government Technical Representative   |
| 4.4      | 3.5   | Final Technical Report                   | 1 EA | Within 30 calendar days after CG-Nicalon™ braided fabric delivery                  | Delivered to Government Technical Representative and Contract Officer electronically in accordance with NFS 1852.235-73 and contract. |

## 5.0 Non-Standard Braid Practices

Any use of braid fabrication aids which may include, but not be limited to, yarn lubricants and weave stabilizers shall be proposed to the Government prior to being practiced for the tasks detailed in this statement of work.

## 6.0 Period of Performance

The total period of performance for this statement of work shall not exceed 120 calendar days following the contract award date.

## 7.0 List of Government Furnished Property (GFP)

Pursuant to FAR 52.245-1 (DEVIATION) (1852.245-76) (SEP 2007) and for performance of work under this contract, the Government will make available Government property identified below or in Attachment N/A of this contract on a no-charge-for-use basis pursuant to the clause at FAR 52.245-1, Government Property. The Contractor shall use this property in the performance of this contract at applicable sites, on a task order basis, and at other location(s) as may be approved by the Contracting Officer. Under FAR 52.245-1, the Contractor is accountable for the identified property.

| Item No. | Task Ref. | Date to be Furnished to the Contractor (on or before)                          | Item Description            | Acquisition Date | Acquisition Cost | Qty. | If Equipment |       |            |
|----------|-----------|--|-----------------------------|------------------|------------------|------|--------------|-------|------------|
|          |           |  |                             |                  |                  |      | Manufacturer | Model | Serial No. |
| 7.1      | 3.4       | 7 days following Large-scale Braided Fabric task 3.4 authorization to proceed. | Ceramic Grade Nicalon™ yarn | September 2011   | \$100,000        | TBD  |              |       |            |

## 8.0 Contract Selection Criteria

Award of this contract shall be based on the following experience/facilities:

- 9.1 Experience braiding with technical fibers such as but not limited to graphite, and aramids.
- 9.2 Facilities and manufacturing equipment sufficient to successfully complete the tasks identified within this statement of work.
- 9.3 Total cost to perform the work detailed in the contract. The proposed cost shall include a breakdown for each subtask (3.1, 3.2, 3.3, 3.4, and 3.5).
- 9.4 Technical approach and compliance with the detailed technical requirements. The information provided should include, braiding approach for subscale and large-scale braiding subtasks, facility braiding capabilities and description of handling and weaving equipment to be used.
- 9.5 Ability to meet subscale and large-scale deliverable dates.
- 9.6 Relevant experience and past performance. The information provided should include a description of similar braiding operations and products delivered with substantive evidence of past performance.